

# **An Air Deployed Multi-Cycle Ocean Profiler for Intelligence, Surveillance, and Reconnaissance**

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## **LONG-TERM GOALS**

To realize an innovative approach, using a gliding autonomous underwater vehicle (AUVG) as a mobile intelligent relay or gateway, connecting an underwater acoustic network to an atmospheric radio network. There is a deployable network of acoustic modems attached to sensor suites for scientific and surveillance purposes (Seaweb and DADS). A communication path to an above-sea control center is required. Slocum gliders equipped with acoustic, radio, and satellite modems will complete the effectiveness of the system by acting as a crossband repeater to transfer data and commands. The Slocum glider moves both horizontally and vertically, driven in a saw tooth vertical profile by variable buoyancy. Long endurance and long-range mobility, silent operation, clandestine features, and inherent surfacings for navigation and communication make Slocum a very suitable platform for this technology. Slocum presents a low-profile, non-permanent target, which is very difficult to detect. In operation, Slocum has the capability of being deployed a distance from and transiting to/amongst the littoral sea-floor network, keep virtual station in one area, store and forward messages, and provide water column environmental sensor data.

Webb Research Corporation (WRC) proposes to build two dedicated Slocum gliders to demonstrate this system approach in upcoming Seaweb and DADS trials.

## **OBJECTIVES**

Integrate a Telesonar modem into a Slocum glider with an appropriate transducer. Develop software to recognize and operate the modem. Investigation of RF communication enhancements, critical as this is the above-sea means for the data to reach its appropriate destination.

## **APPROACH**

The core team consists of Doug Webb, president and engineer at WRC, Clayton Jones a project engineer at WRC, Tom Campbell a software engineer residing at WRC (Dinkum Software), and Bill McElroy a consultant residing at WRC (MAST).

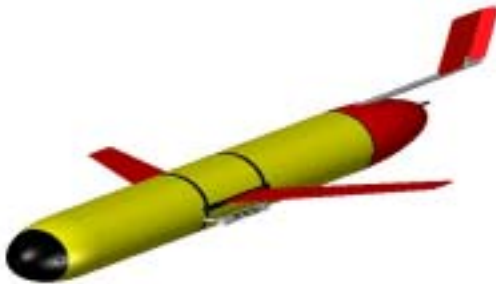
Doug Webb and Clayton Jones were responsible to accommodate the Benthos Telesonar 885 modem and an appropriate transducer in the glider. To facilitate this a new glider forward end cap was created for the transducer assembly and a mid-payload section was designed to aid in the ease of adding or

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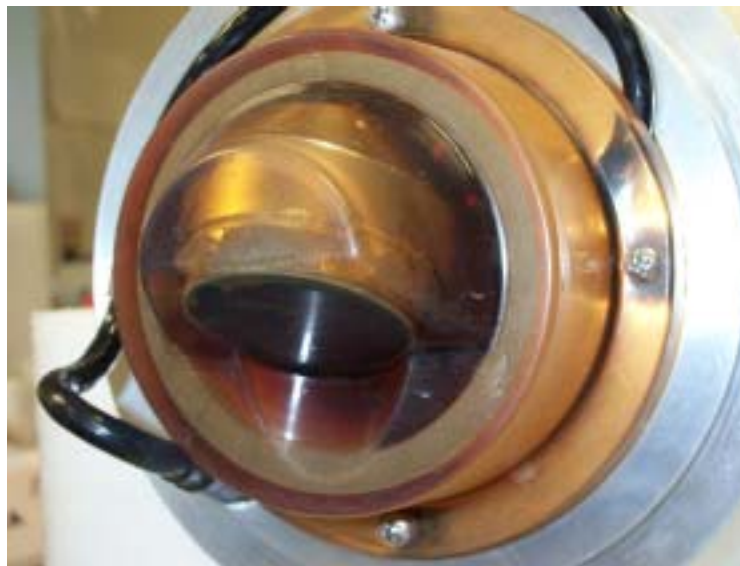
changing sensor suites. Tom Campbell, project software engineer for glider control code, undertook the effort to create a payload computer system, separate from the glider control computer, to interface with the Telesonar modem. Clayton Jones worked on the combined 10 KHz and 200 KHz rings with the aid of Benthos Incorporated. Bill McElroy and Clayton Jones exercised the vehicle in local waters testing the acoustic link. Clayton Jones tested present RF modem capabilities and investigated enhancing performance.

## **WORK COMPLETED**

The mechanical and electrical accommodation of a Benthos Telesonar 885 modem into a Slocum glider. A redesign of the vehicle's architecture has resulted in a modular payload bay (Fig 1). In addition, a cooperative effort with Benthos Inc. has resulted in a combined transducer system for both Telesonar and vehicle altimeter. The vehicle design was adapted to allow mounting of the transducers in the nose (Fig 2). It was deemed important to have the modem transducer ring in the nose to ensure that it submerged when the glider is communicating via RF to allow bi-directional repeating.



*Figure 1. Slocum Glider shown with replaceable center payload bay.*



*Figure 2. Combined 9 – 14 kHz ring transducer and 200 kHz altimeter mounted to glider nose.*

Software development to provide “store and forward” repeating of acoustic packets received when the glider is sub-surface. Current gateway capability includes only immediate retransmission of received packets. Also incorporated were software changes to recognize acoustic communications as a mission behavior.

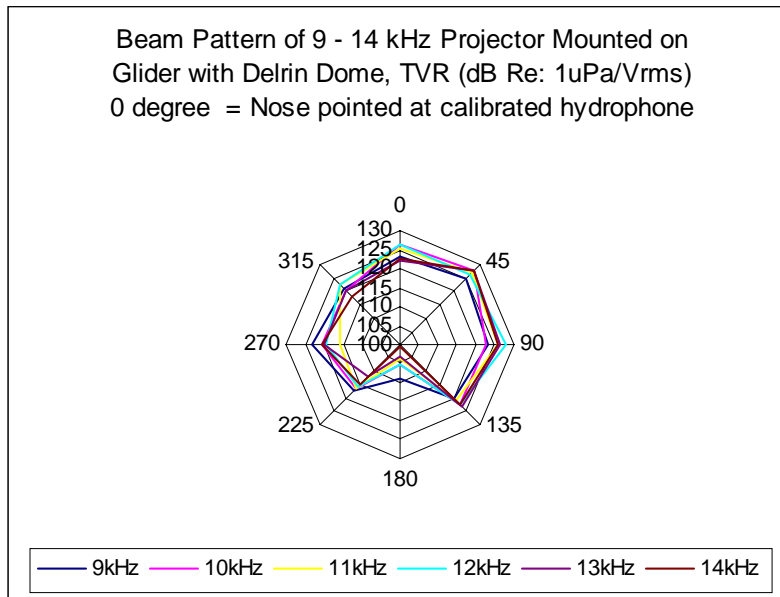
Presently all of the vehicle’s antennae GPS, RF modem, and ARGOS are encapsulated within the fiberglass tail fin to maintain a low drag (Fig 1) form factor. Provisions have been made for greater reserve buoyancy and lift of the tail fin antenna. This was tested in local waters and at the LEO 15 site in NJ. A whip, or sting, style antenna has been constructed with a pressure rating of 10,000 PSI as an alternative if greater antenna exposure is required.

## **REUSLTS**

The effort to create a modular payload bay for the Slocum glider has proven to be a significant advance in vehicle capability. Payload sections can be modified for other sensors suites and simply (within weight and volume considerations) swapped in. The incorporation of protocol to a separate payload computer allows for the user to develop adaptive science or intelligence payloads independent of the actual glider hardware on whichever platform is chosen. This functional division of architecture and modularity has a wide following and commercially enhances the salability of the vehicle.

Preliminary testing of the acoustic link has shown that there is a directivity associated with the mounting of the transducer in the nose of the glider. The forward hemi of the glider is the most sensitive and the aft hemi decreases in sensitivity (Fig 3). This was an expected outcome of transducer placement and future work may include different types and placement techniques to improve performance. Acoustic power settings and communication protocols also played a role in performance. In discussions with Benthos, it has been acknowledged that automatic acoustic modem training (seeking parameters which will gain best performance) will be a key future issue.

The RF modem portion of this arrangement (Freewave 900 MHz) has been shown to work from a repeater at 200 feet elevation to the glider in a 1 foot sea state at a distance of 21 nautical miles. With a 4 – 6 foot sea state the operations drop to approximately 10 nautical miles due to wave shadowing of the signal. A direct link is rated at 115 Kbaud, a link through a repeater modem approximately halves the data rate, and rough sea conditions reduce the effective baud rate even further. A successful trial was run using an RF repeater on an airplane flying at 7000 feet altitude giving a minimum of 20 nautical miles in a 4 – 6 foot sea state. Due to prescribed flight plans a maximum range was not tested. Provisions have been made for greater reserve buoyancy and lift of the tail fin antenna. While surfaced the glider rides very well and is not subject to much washover. Research has gone into erecting a light whip style antenna to obtain greater range. The ultimate goal is to integrate a global bi-directional satellite communications system, while retaining the RF modem system for high-speed local communications. There are several choices and preliminary investigation and antenna design were conducted.



**Figure 3. Acoustic beam pattern of 9 – 14 kHz transducer mounted in the nose of the glider, indicating best performance with the nose orientated towards the calibrated hydrophone and degradation as the nose is oriented away from the calibrated hydrophone.**

## IMPACT/APPLICATIONS

This research will culminate in a low-cost, high endurance, critical tool for Navy Fleet purposes. In addition, this support will leverage commercial viability. Several Universities and groups are interested and have placed orders for Slocums as littoral survey vehicles that report environmental information from such sensors as ctd, red tide detector, optical (fluorometer, PAR, transmissometer), and hydrophones. Gliders were initially developed with SBIR funding and are becoming a commercial success with 10 Slocum gliders ordered by various users and a potential of 5 more awaiting funding. The present SBIR program allows for development, test, and improvements benefiting specific purposes defined by the Navy and the commercial market. As a vehicle, Slocum will be enhanced and proven through these series of trials to carry out long-range remote missions with greater robustness and capabilities, translating into usefulness to users. There is direct use/benefit for autonomous gateway technology in the scientific world. Researchers wish to make yearlong deployments of seismic or moored equipment in the deep ocean. The real time data collection from these is difficult, requiring a deep-moored buoy, a ship, or oceanic cables. An alternative approach is to incorporate the acoustic modem and RF telemetry technology proven here on a thermally powered Slocum. This thermal glider is being developed in parallel with the battery version, where the buoyancy drive is harvested from the temperature differentials from surface to deep-ocean, allowing for much longer deployments. In essence, the thermal powered Slocum “refuels” each time it completes a surface-to-1000-meter dive cycle. A station-keeping (virtual mooring) glider diving to 1200 meters can extract bottom mounted sensor data acoustically, surface, and re-transmit through a satellite communication link. Furthermore, the glider will gather valuable water column profiles four to five times a day. Providing a path for development, maturity, and robustness increases the scope of commercial viability. We feel strongly that the Slocum gliders, both electrically and environmentally powered, will have a significant role in both Navy and scientific use.

## **TRANSITIONS**

Adding expansion capabilities to the present Slocum glider benefits all users and potential commercial sales. In particular, Defence Research Establishment Atlantic (DREA) has added the integration of the Benthos Telesonar modem to their order of 2 Slocum gliders.

## **RELATED PROJECTS**

Woods Hole Oceanographic Institution (WHOI) -- WRC will deliver 3 Slocum gliders to Dr. David Fratantoni which will be used as a coordinated fleet to provide nearly-continuous hydrographic and optical measurements over a one year period at the Martha's Vineyard Coastal Observatory (MVCO).

WHOI -- WRC will deliver 2 Slocum-Thermal gliders to Dr. David Fratantoni to be used as an autonomous observing network near the long-term Bermuda Atlantic Hydrographic Time Series station.

Rutgers -- WRC has been involved in the LEO-15 project during July 1999, 2000, and 2001. We expect to continue collaboration with Dr. Scott Glenn and colleagues from Rutgers University in this multi-institution National Ocean Partnership Program (NOPP). WRC will deliver 3 Slocum gliders to Rutgers under a DURIP, and there is a NSF proposal for 4 additional Slocum gliders.

DREA -- WRC will deliver 2 Slocum gliders with integrated Telesonar modems to the Canadian defense lab for trials in January 2001.

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